ECE 595

INTRODUCTION TO MOBILE EDGE COMPUTING AND NETWORKING

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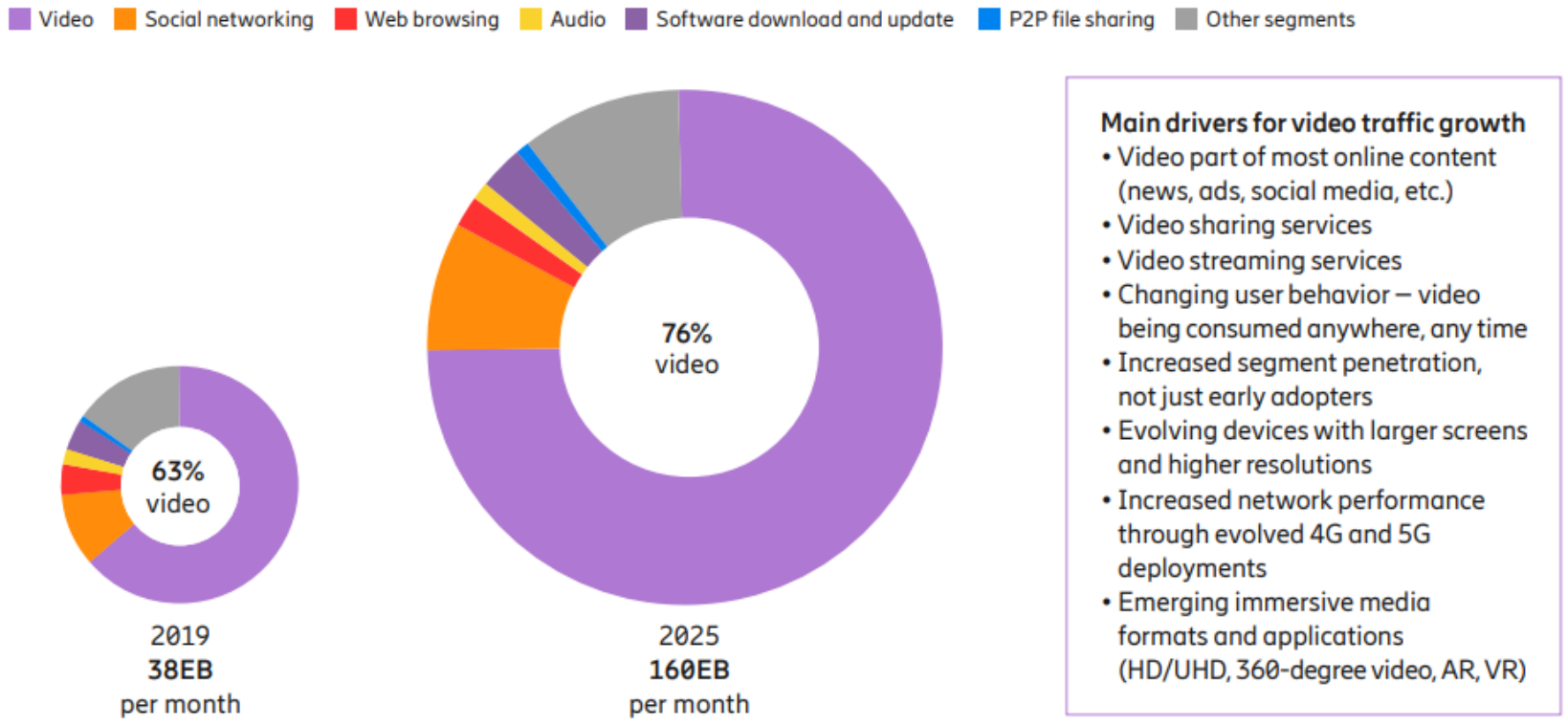
Data Explosion

- Data explosion: billions of mobile phones generate a massive amount of data streams over time.



[1] Traffic from embedded video in web browsing and social media is included in the application category "Video"

Source: Ericsson Mobility Report Nov 2019 [online]. Available: https://www.ericsson.com/4acd7e/assets/local/mobility-report/documents/2019/emr-november-2019.pdf

Data Explosion

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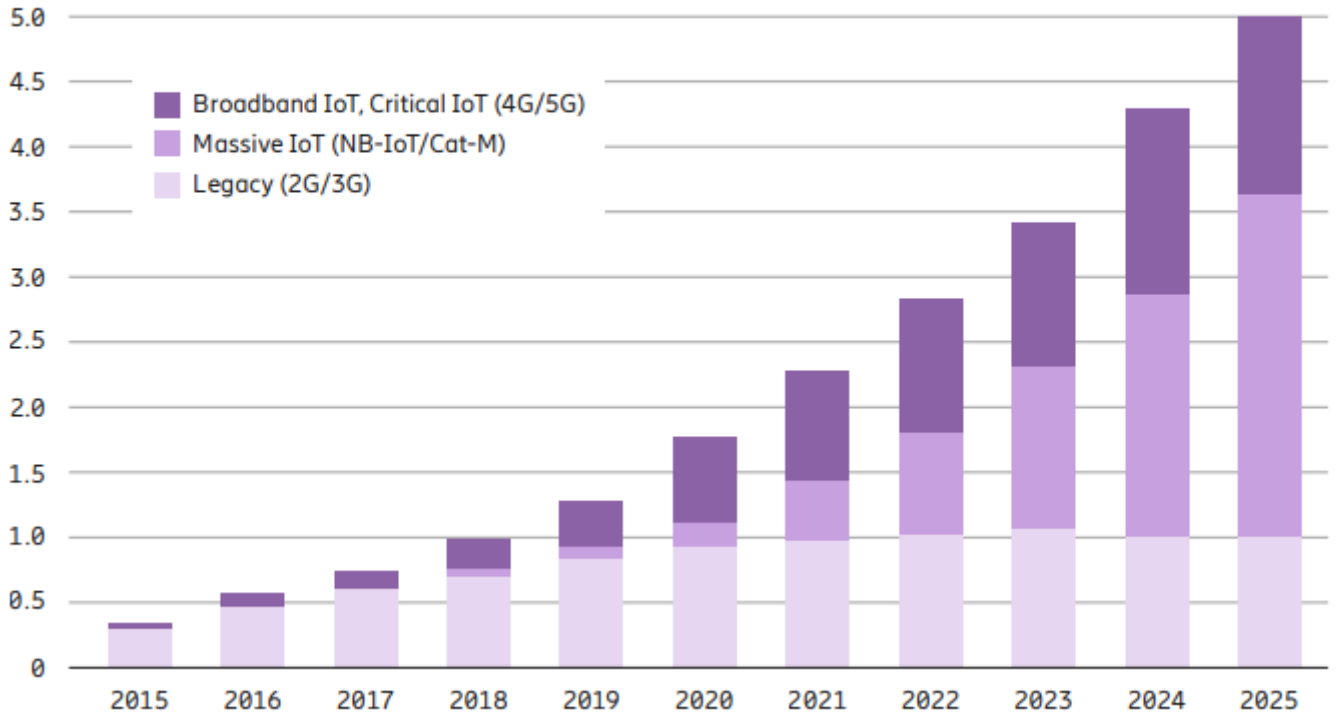
Figure 16: Cellular IoT connections by segment and technology (billion)



Source: Ericsson Mobility Report Nov 2019 [online]. Available: https://www.ericsson.com/4acd7e/assets/local/mobility-report/documents/2019/emr-november-2019.pdf

Data Explosion

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Source: 10 Facebook Stats Every Marketer Should Know in 2020 [online]. Available: https://www.oberlo.com/blog/facebook-statistics

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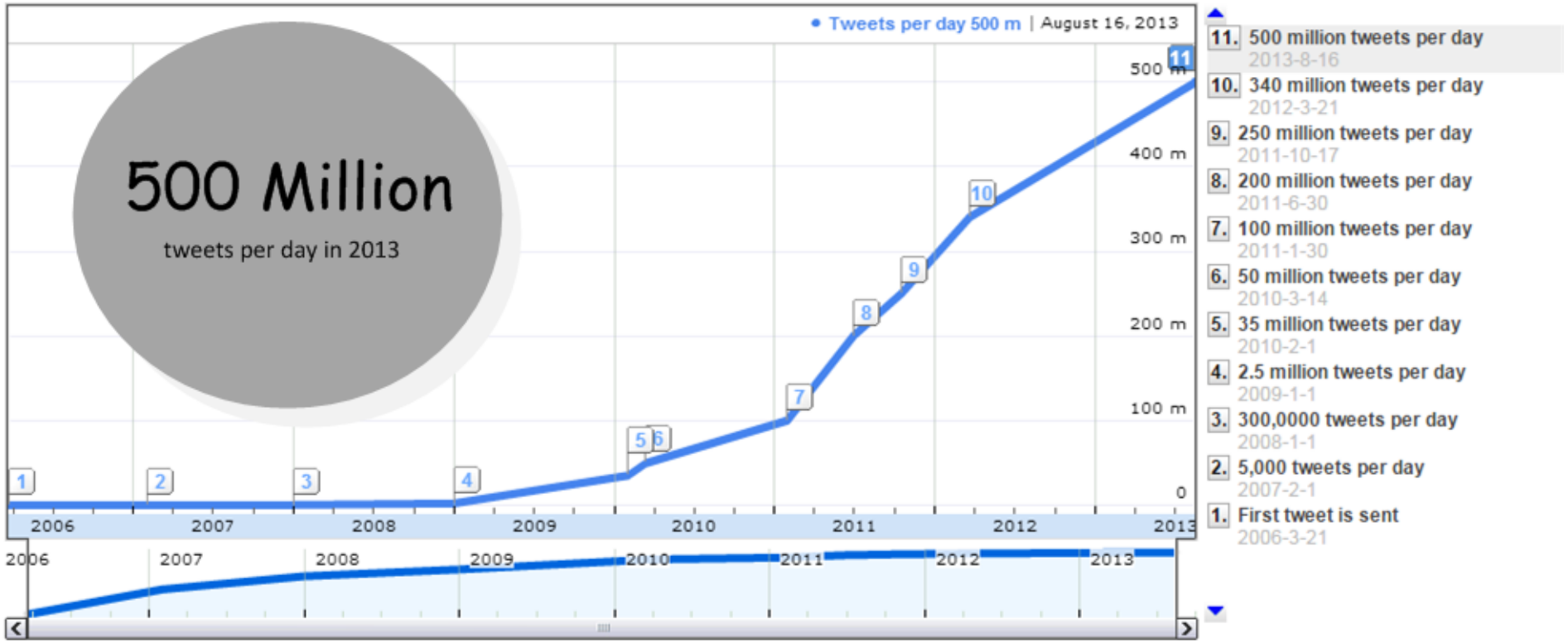


Source: Twitter Usage Statistics [online]. Available: http://www.internetlivestats.com/twitter-statistics/

Value of Big Data

❑ How valuable are big data?

- ✓ According to the Mckinsey report, the potential value of global personal location data is estimated to be $100 billion in revenue to service providers over the next ten years and be as much as $700 billion in value to consumer and business end users.

Source: J. Manyika et al., Big data: The Next Frontier for Innovation, Competition, and Productivity. San Francisco, CA, USA: McKinsey Global Institute, 2011, pp. 1–137

Value of Big Data

❑ How valuable are big data?

✓ Police apply big data analytics to reduce crimes and improves public safety:

Memphis Police analyzed crime history to predict how to effectively deploy officers. Consequently, the serious crime has been reduced by 30%, including a 36.8 percent reduction in crime in one targeted area and up to 15 percent reduction in violent crime.

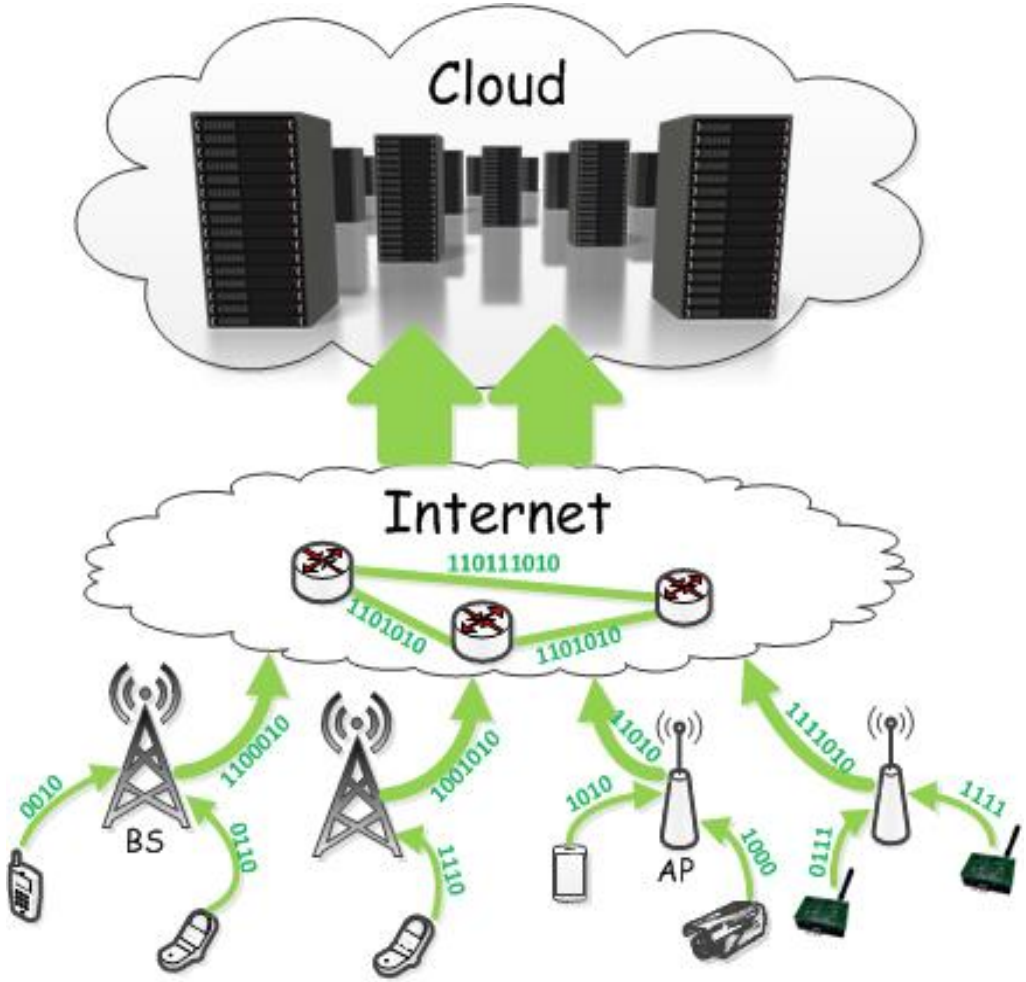
Miami Dade Police, using the statistical analysis, found similarities in crime patterns to help break cold cases. As a result, they achieved a 73 percent "hit rate" in identifying suspects, significant reductions in the number of cold cases, faster arrests, and a reduction in repeat crimes

------source: http://www.ibmbigdatahub.com/blog/how-analytics-reduces-crime-and-improves-public-safety

Leveraging Big Data

❑ How to leverage big data?

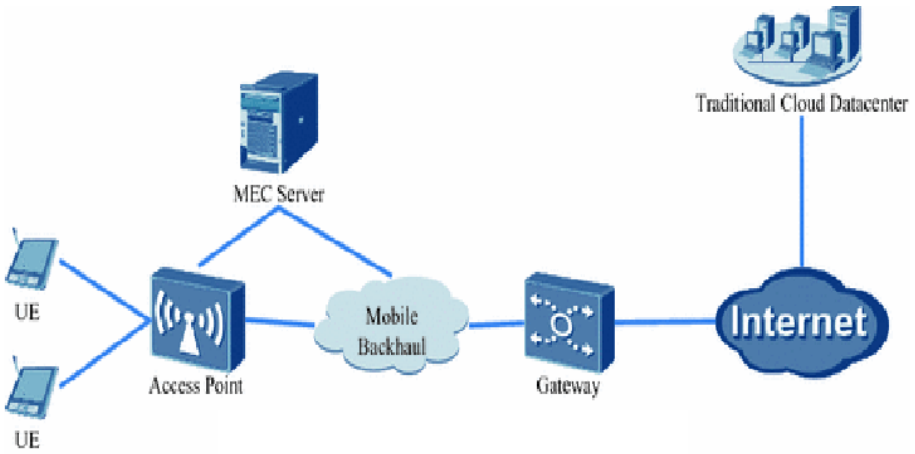
- ✓ Traditionally, a massive amount of data steams generated by the smart devices are processed and stored in the centralized cloud by utilizing Hadoop-based large-scale data analysis framework.
- ✓ Due to the variety of disparate data sources and the sheer volume, it is difficult to collect and integrate data with scalability from distributed locations in real time.
- ✓ The value of data diminishes as time passes by.



Mobile Edge Computing

❑ Concept of mobile edge computing (MEC)

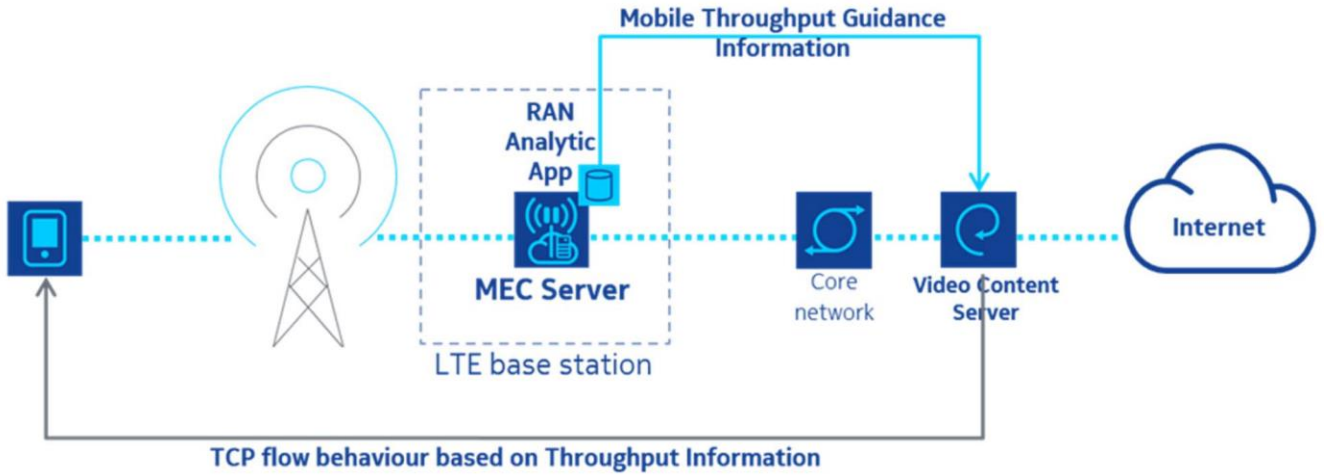
- MEC provides cloud-computing capabilities and IT service environment within the Radio Access Networks (RAN) in close proximity to mobile device.



  - ✓ MEC aims to reduce latency, ensure highly efficient network operation, service delivery and ultimate personal experience.
  - ✓ The term "Edge" in this context means the radio base station itself (eNodeB, RNC, etc.), and servers connect to the radio access network (e.g., at "aggregation points").
  - ✓ The presence of MEC server at the edge of the RAN allows exposure to real-time radio and network information (such as subscriber location, cell load, etc.) that can be leveraged by applications and services to offer context-related services.

❑ MEC applications

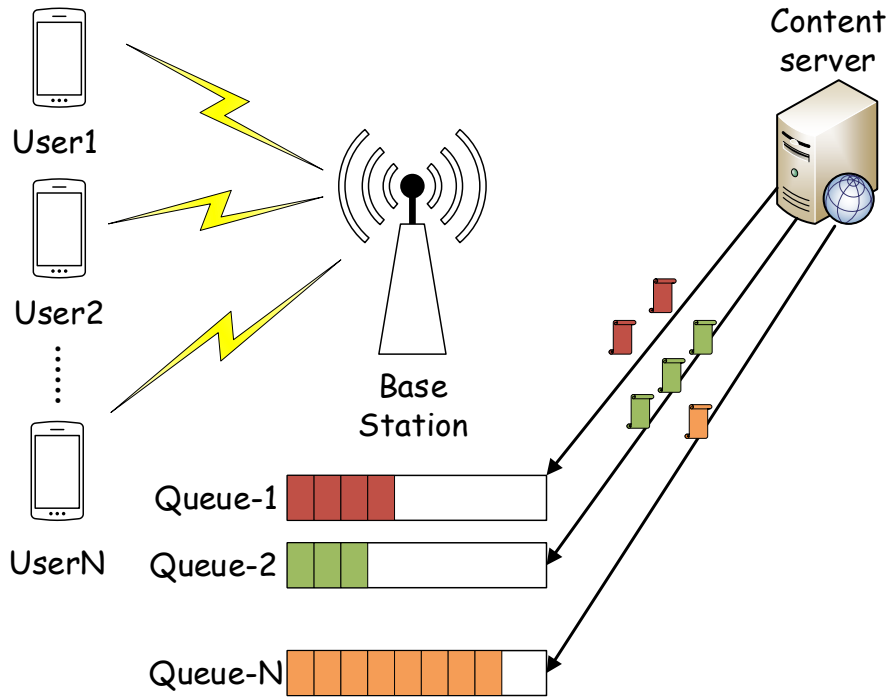
➢ Intelligent video acceleration



- ✓ A radio analytics application is running in a MEC server. It provides the video server with a near real-time indication on the throughput estimated to be available at the radio downlink interface.
- ✓ The video server may use this information to assist TCP congestion control decisions.
  - selecting the initial congestion window size
  - setting and adjusting the congestion window size

❑ MEC applications

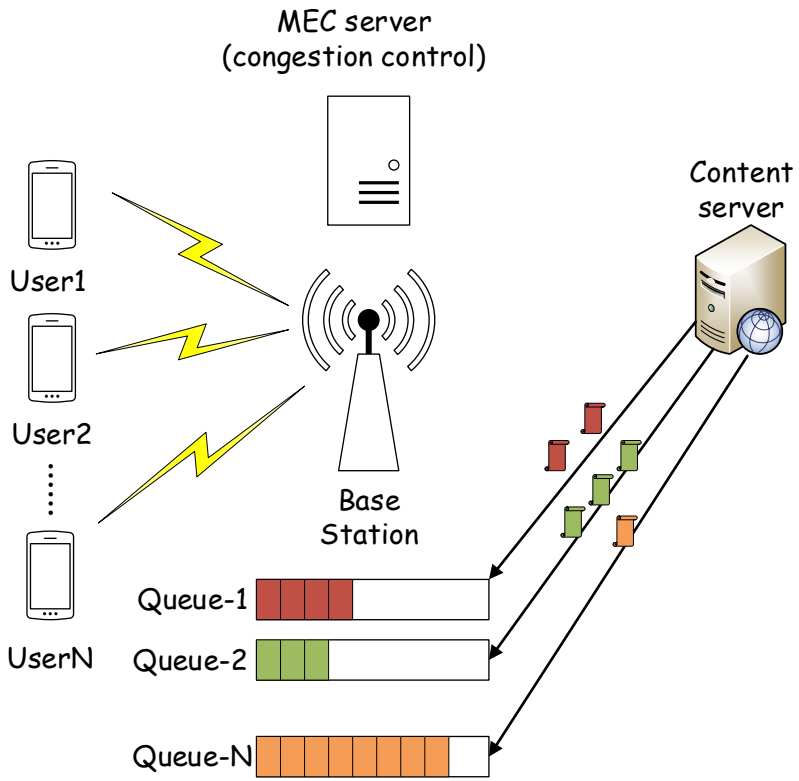
➢ Intelligent video acceleration



- ✓ The base station maintains a virtual queue for each mobile user. The virtual queue buffers the data stream from the content server.
  - Average arrival rate of a virtual queue=average data rate of downloading data from the content server to the base station.
  - Average departure rate of a virtual queue= average data rate of downloading data from the base station to the mobile user.
- ✓ Average arrival rate > Average departure rate → The length of the virtual queue keeps increasing
- ✓ The length of the virtual queue> the size of the virtual queue → Packet loss
- ✓ Similarly, if arrival rate < departure rate, then ?

❑ MEC applications

➢ Intelligent video acceleration

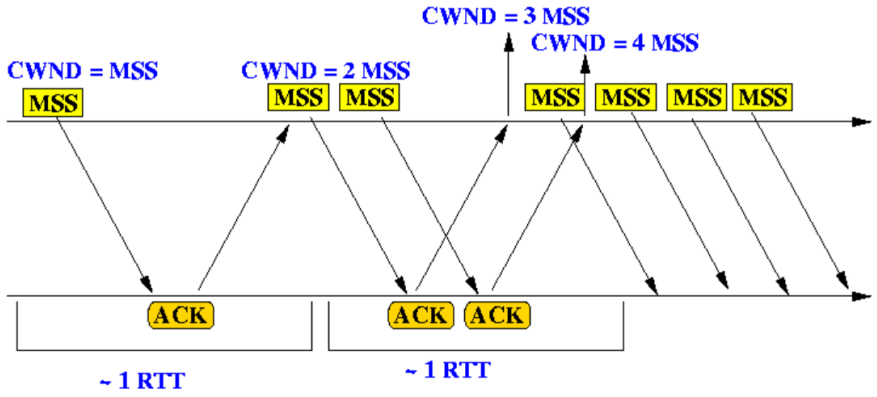


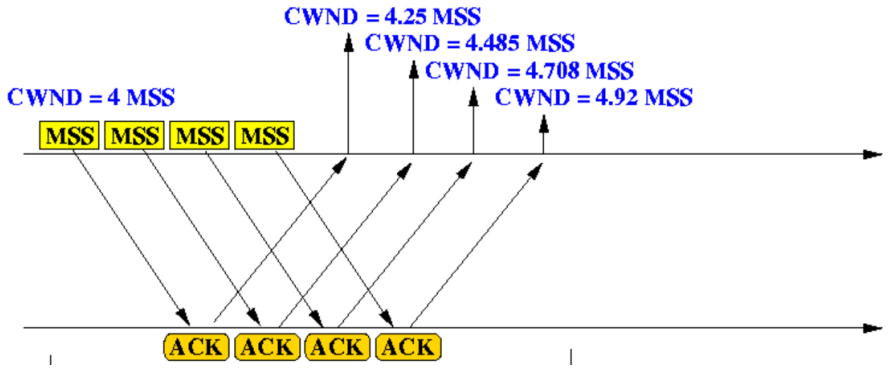
- ✓ The MEC server is used to facilitate congestion control.
  - Adjusting the departure rate of a virtual queue by informing the BS to adjust the scheduling (i.e., increasing/decreasing bandwidth of a mobile user) based on the arrival rate of the virtual queue.
  - Adjusting the arrival rate of a virtual queue by informing the content server to change the congestion window (cwnd) of the TCP flow based on the departure rate of the virtual queue.

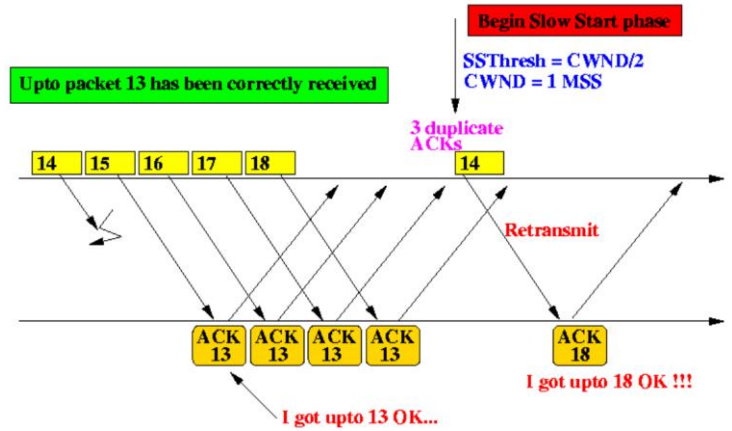
- ✓ Congestion control in traditional TCP-- Tahoe.
  - CWND, which is maintained by the sender (content server), determines the total number of unacknowledged packets that may be in transit.
  - CWND starts with a value equal to a multiple of the maximum segment size (MSS), e.g., CWND= 1 MSS.
  - After each ACK is received, the sender increases CWND by 1 MSS---Slow Start Process

❑ MEC applications

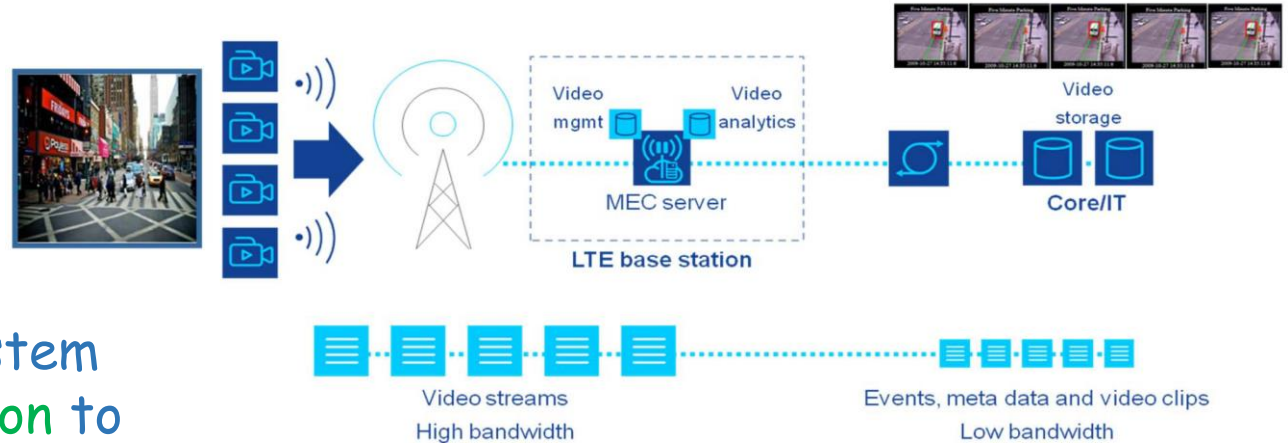
- ➢ Congestion control in traditional TCP -Tahoe
  - ✓ Once CWND reaches the slow start threshold (ssthresh), CWND is increased linearly to avoid the congestion, i.e.,
    cwnd := cwnd + 1 MSS* 1 MSS/cwnd
    For example, if sshresh=4 MSS, then..
  - ✓ When the sender detects packet loss (receipt of three duplicate ACKs or the retransmission timeout when ACK is not received), CWND is decreased to the initial value (one MSS) and ssthresh=CWND/2.







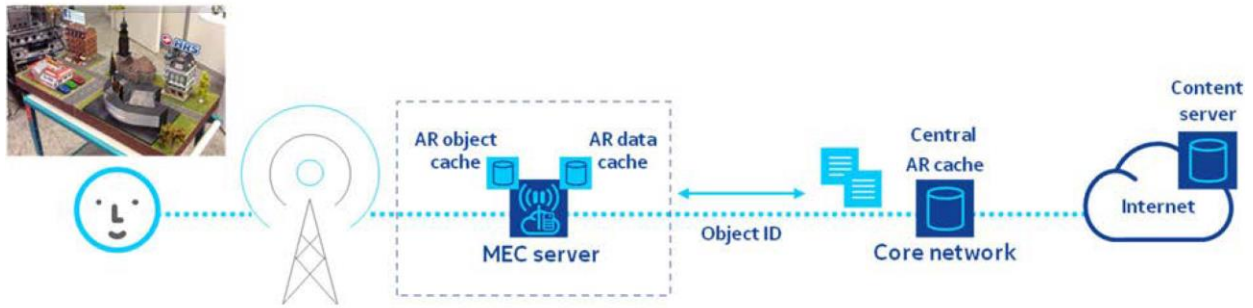
❑ MEC applications



- ➢ Video stream analysis service
  - ✓ Consider a video based monitoring system such as vehicle license plate recognition to monitor vehicles entering and exiting an area of the city, car parks, for security purposes, etc.
  - ✓ Performing video analysis at the mobile edge mitigates the need to transmit high data video streams over the network.
  - ✓ Note that analyzing video at the mobile edge is not always an optimal solution.

❑ MEC applications

➢ Augmented reality services



- ✓ Augmented reality (AR): the cameras (of smartphones or smart glasses) capture the point of interests and the application displays additional information related to the point of interests.
- ✓ AR service requires an application to analyze the output from a device's camera and/or a precise location of a device, i.e., understand what is the user looking at.
- ✓ After analyzing such information, the AR application can provide additional information in real-time to the user. If the user moves (by looking at a different object), the information needs to be updated.
- ✓ Based on the locality feature of the AR data/objects, MEC server can cache those AR data/objects to speed up the AR data/objects fetching.
- ✓ Additionally, the processing of a device location or camera view can be performed on a MEC server rather than on a more centralized server or on the device itself.

❑ MEC applications

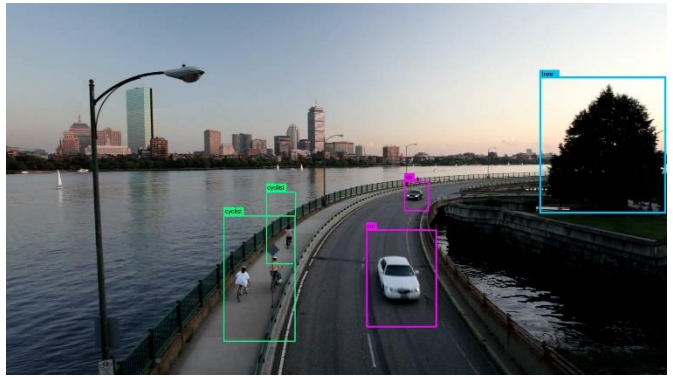
➢ Augmented reality services—2D Lego Assembly

- ✓ Video from the camera on the smart glasses is streamed to the cloudlet (MEC server). Processing of video frames and creation of guidance are done entirely on the cloudlet.

❑ MEC applications

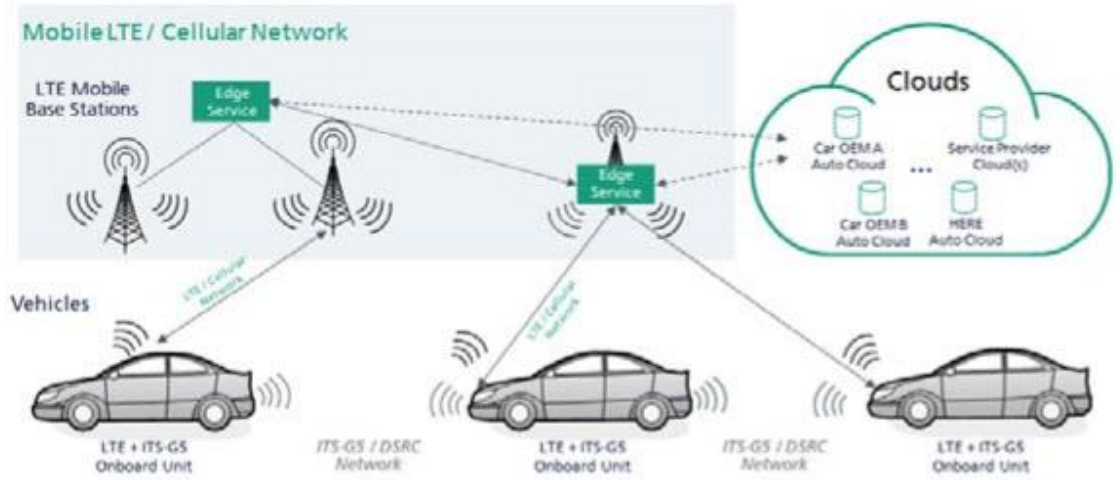
➢ Assistance for intensive computation

- ✓ In order to maximize battery life and simplify a device or sensor in order to make it low cost, intensive computation and decision making may be offloaded to the computing resources in the network—computational task offloading.
- ✓ In some cases, devices may also require information from other remote sources (which is fed into the data processing required to do some decision making, and then fed back to the device).
  - For example, image recognition by a robotic device (e.g., a drone).
- ✓ An MEC server can be used to host high performance computation capabilities, which can take information from multiple sources. Such computation can be done in very short timescales, and the result will be fed back to remote devices (which may require information to perform a further action).



❑ MEC applications

➢ Connected vehicles



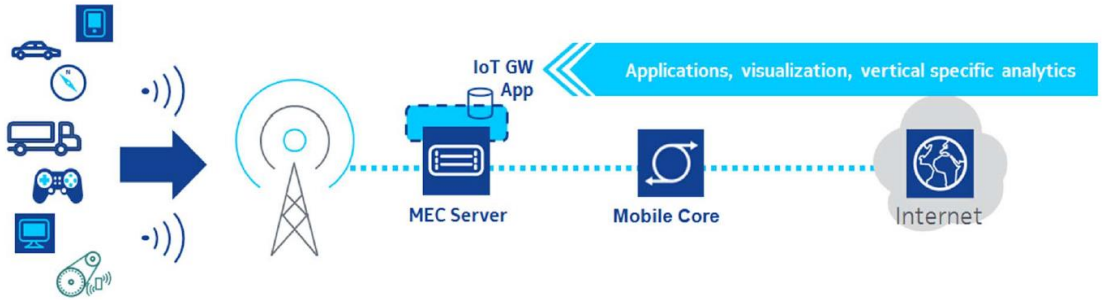
- ✓ The number of cars and other vehicles becoming more 'connected' using technologies such as Short Range Communications (SRC) for short distance and Long Term Evolution (LTE) for long distance connectivity is increasing.
- ✓ Communications among vehicles and other road-side sensors (e.g., cameras, radar sensors, RFID readers) are intended to increase the safety, efficiency, and convenience of the transportation system.
  - For example, notifying of road hazards, reduce traffic congestion, sensing the vehicles behaviors, etc.
- ✓ As the number of connected vehicles increases, the volume of data will continue to increase along with the latency requirements. Data stored and processed centrally may be adequate for some use cases, it can be unreliable and slow for all use cases.
- ✓ MEC servers, which are deployed at the LTE base station site, to provide roadside functionality with low latency.

❑ MEC applications

➢ Connected vehicles

❑ MEC applications

➢ IoT gateway service



- ✓ The various devices are getting connected over different forms of connectivity, such as 3G, LTE, Wi-Fi or other spectrum.
- ✓ There is a need for a low latency aggregation point to manage the various protocols, distribution of messages and for the processing of analytics.
- ✓ The MEC Server provides the capability to resolve these challenges.